(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 407 160 A2

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 90307289.0

(22) Date of filing: 04.07.90

(51) Int. Cl.5: H01J 65/04, H01J 61/12

(30) Priority: 07.07.89 GB 8915611

(43) Date of publication of application:
09.01.91 Bulletin 91/02

(84) Designated Contracting States:
AT BE CH DE DK ES FR GB GR IT LI LU NL SE

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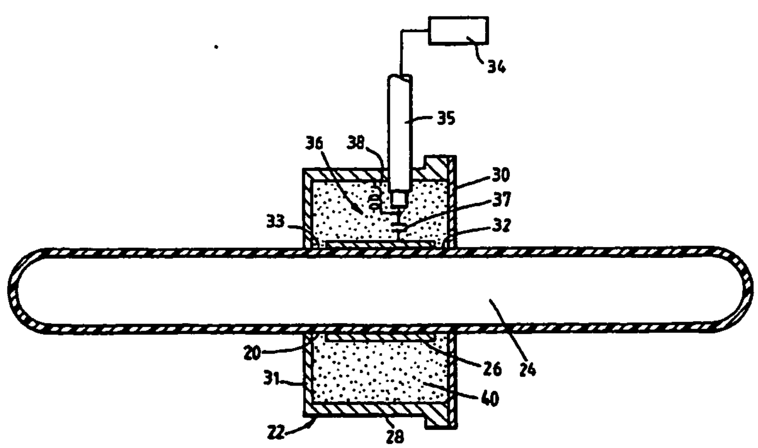
(54) A discharge tube arrangement.

(57) A method of generating visible light from a discharge tube having walls made of a light-transmissive dielectric material. The discharge tube containing a fill comprising at least one compound selected from a group consisting of metal halides and metal oxyhalides. The method comprises the step of applying a radio frequency electric field over a part of a wall of the discharge tube at a power sufficient to excite a surface wave in the fill, whereby the fill is excited to generate visible light.



EP 0 407 160 A2

A DISCHARGE TUBE ARRANGEMENT

This invention relates to a discharge tube arrangement and in particular to such an arrangement for use as a light source.

It is known, e.g. as disclosed in EP 0225753A2 (University of California), to generate and sustain a low pressure discharge in a gas by using electromagnetic surface waves. Surface waves are created by an energizer (also known as a launcher) which is positioned around and external of, but not extending the whole length of, a discharge tube containing the gas. In such an arrangement, it is not necessary to provide electrodes inside the discharge tube. The power to generate the electromagnetic wave is provided by a radio frequency (r.f.) power generator.

It is proposed that such an arrangement be used as a visible light or a UV source. To provide a visible light source, the discharge tube could be a generic fluorescent lamp discharge tube containing a mix of inert gases and mercury vapour (e.g. argon gas and mercury vapour) and having on its inner surface a phosphor which converts 254nm U.V. radiation to visible light. To provide a U.V. source, the discharge tube could be a generic germicidal or curing lamp discharge tube constructed of quartz glass and containing a mix of inert gases and mercury vapour, but with no phosphor.

However, there is a disadvantage in the use of a fluorescent type discharge tube arrangement to produce visible light. As indicated hereinbefore, a discharge tube containing a mix of inert gases and mercury vapour radiates primarily in the U.V. so that a phosphor must be used to convert the U.V. to visible light. In this process about half the energy of the U.V. quantum is lost.

It is theoretically possible to use a volatile metal halide to produce a low pressure discharge which emits visible light. Such metal halides are extremely reactive but their use in certain types of electrodeless discharge tube arrangements has been investigated..

In the H-Discharge (also known as the 'inductively coupled discharge') arrangement, the discharge is produced as a single turn loop forming the secondary of a transformer; the primary is formed by a coil, which may have a high permeability core. It has been found that low pressure metal halide discharges operated in this mode exhibit a wide range of instabilities and so are impractical as light sources.

In the E-discharge arrangement, the discharge vessel is placed between the plates of a capacitor excited by a high frequency source. However, the current to sustain the discharge has to flow as displacement current through the glass or silica wall of the discharge vessel and so it is difficult to produce a discharge having a significant amount of power. Though the current increases with the frequency of excitation, so also does the dielectric loss due to the glass or silica wall, resulting in significant power losses in the wall of the discharge vessel.

Another type of electrodeless discharge is known as the 'ultra-high frequency' discharge. In such a discharge, the wavelength of the exciting source is shorter than or comparable with the discharge dimension. Such discharges have been investigated over many years but problems of power generation and geometry mean that they do not offer practical possibilities as commercially viable light sources.

It has been found that discharges operated in these three prior art modes using a low pressure metal halide fill tend, under certain, ill-defined conditions, to form tentacles which attach themselves to the wall of the discharge vessel. This causes intense local hot spots and so failure of the light source. The discharges produced are also unstable and present a fluctuating load to the power generator leading to difficulties in matching. Furthermore, in the discharge arrangements used, the structure used to excite and sustain the discharge tends itself to obscure the discharge, reducing the amount of light that can reach the observer.

It is an object of the present invention to provide a discharge tube arrangement for use as a source of light which at least alleviates the problems outlined hereinbefore.

According to a first aspect of the present invention there is provided a method of generating visible light from a discharge tube having walls made of a light-transmissive dielectric material, the discharge tube containing a fill comprising at least one compound selected from a group consisting of metal halides and metal oxyhalides, the method comprising the step of applying a radio frequency (r.f.) electric field over a part of a wall of the discharge tube at a power sufficient to excite a surface wave in the fill, whereby the fill is excited to generate visible light.

The inventors have surprisingly found that it is possible to achieve a stable, well-behaved, low pressure metal halide discharge in a discharge tube without electrodes by exciting the discharge using surface waves. The metal halide is at least partially dissociated and light is emitted in the visible region from both atomic and molecular fragments. It is envisaged that metal oxyhalides will exhibit a similar behaviour to metal halides.

According to a second aspect of the present invention there is provided a discharge tube arrangement

for generating visible light, the arrangement comprising a discharge tube having walls made of a light-transmissive dielectric material, the discharge tube containing a fill comprising at least one of a group consisting of metal halides and metal oxyhalides; the arrangement further comprising means for applying a radio frequency (r.f.) electric field over a part of a wall of the discharge tube at a power sufficient to excite a surface wave in the fill, whereby, in use, the fill is excited to generate visible light.

A discharge tube arrangement provided in accordance with this aspect of the present invention can be used to generate visible light by the method provided in accordance with the first aspect of the present invention.

Preferably the means for applying an r.f. electric field comprises an r.f. power generator and a launcher. Accordingly, the applying means can be arranged so as not to substantially obscure the discharge and the discharge itself can have a length of the order of centimetres to metres and a diameter of the order of millimetres to centimetres depending on the power used.

Embodiments of the invention will now be described, by way of example only, and with reference to the accompanying drawing which shows a cross-sectional side view of a discharge tube arrangement provided in accordance with the present invention.

As shown in Figure 1, a discharge tube arrangement comprises a discharge tube 20 mounted in a launcher 22. The discharge tube 20 is formed of a light-transmissive, dielectric material, such as glass, and contains a fill 24.

The launcher 22 is made of an electrically conductive material, such as brass, and formed as a coaxial structure comprising an inner tube 26 and an outer tube 28. A first plate 30, at one end of the outer tube, provides a first end wall for the launcher structure. At the other end of the outer tube 28, a second plate 31, integral with the outer tube 28, provides a second end wall. The inner tube 26 is shorter than the outer tube 28 and so positioned within the outer tube 28 as to define a first annular gap 32 and a second annular gap 33. Each of the first plate 30 and second plate 31 has an aperture for receiving the discharge tube 20. The outer tube 28, the first plate 30 and the second plate 31 form an unbroken electrically conductive path around, but not in electrical contact with, the inner tube 26 to provide an r.f. screening structure therearound.

Suitable dimensions for the launcher of Figure 1 are as follows:

Launcher length	7-20 mm
Launcher diameter (outer tube 28 diameter)	25-35mm but depends on size of discharge tube 20.
Inner tube 26 length	3-18mm
Inner tube 26 diameter	13mm but depends on size of discharge tube 20.
Length of Launching gap (first gap 32)	0.5-3mm
Length of second gap 33	1-10mm

The thickness of the electrically conductive material is of the order of millimetres, or less, depending on the construction method used.

An r.f. power generator 34 (shown schematically) is electrically connected to the inner tube 26 of the launcher 22 via a coaxial cable 35 and an impedance matching network 36 (shown schematically as comprising capacitor 37 and inductor 38). The r.f. power generator 34, the impedance matching network 36, the coaxial cable 35 and the launcher 22 constitute an r.f. powered excitation device to energise the fill to produce a discharge.

A body 40 of dielectric material inside the launcher 22 is provided as a structural element, to keep the size of the gaps 32, 33 constant and to hold the inner tube 26 in position. The body 40 also helps in shaping the electric field in the gaps 32, 33 for ease of starting or other purposes. Suitable dielectric materials which exhibit low loss at r.f. frequencies include glass, quartz and PTFE. Alternatively, the launcher may be partially or completely air filled, provided that means to support the inner tube are provided.

When the r.f. power supply 34 is switched on, an oscillating electric field, having a frequency typically in the range of from 1MHz to 1GHz, is set up inside the launcher 22. At the first and second gaps 32, 33, this electric field is parallel to the longitudinal axis of the discharge tube 20. If sufficient power is applied, the consequent electric field produced in the fill 24 is sufficient to create a discharge through which an electromagnetic surface wave may be propagated in a similar manner to the arrangement of EP 0225753A2. Accordingly, the launcher 22 powered by the r.f. power generator 34 creates and sustains a discharge in the fill - the length and brightness of the discharge depending, inter alia, on the size of the

discharge tube 20 and the power applied by the r.f. power generator 34. Such a discharge tube arrangement may therefore be used as a light source.

In order to produce a discharge which emits visible light, the fill 24 may comprise a noble gas, such as argon, together with a compound selected from the group consisting of metal halides and metal oxyhalides. Mercury may also be added.

The inventors have tried a fill which contained the noble gas, argon (Ar), together with aluminium chloride ($AlCl_3$). This was found to produce a stable discharge, emitting visible light, when excited by a surface wave.

Halides of metals from the transition series of the periodic table, such as titanium, iron and niobium, can advantageously be used. These halides are sufficiently volatile to produce a vapour pressure at which a discharge can be generated at the wall operating temperatures of the discharge tube. They can be dissociated by electron impact. The resulting excited atoms, ions and molecules emit radiation; the metal atoms have large numbers of relatively low-lying energy levels giving rise to radiation throughout the visible region.

Halides of neodymium (Nd) and other rare earth metals on excitation also give rise to radiation throughout the visible region. They are relatively involatile but can form complexes with other metal halides (known as complexing agents). The vapour pressure of the complex so formed can be factor of 10^5 greater than that of the rare earth metal halide. The complex should have a total vapour pressure exceeding about 10^{-3} torr at the operating temperature of the lamp, e.g. up to 250°C. Examples of complexing agents include the halides (ie chlorides, bromides or iodides - X is Cl, Br or I) of aluminium (AlX_3), indium (InX_3), gallium (GaX_3), tin (SnX_4), titanium (TiX_4) as well as the compound di-iron (III) chloride (Fe_2Cl_6). Examples of complexes include $NdAlCl_6$ (a complex of $NdCl_3$ and $AlCl_3$) and $NaAlCl_4$ (a complex of NaCl and $AlCl_3$).

The inventors envisage that stable discharges can be generated by surface waves from fills containing the following mixtures:

Tin (II) iodide (SnI_2) + sodium iodide (NaI) + $AlCl_3$ + Ar;
$AlVr_3$ + $SnCl_2$ + niobium (V) Chloride ($NbCl_5$) + Ar;
Indium (I) bromide (InBr) + AlC_3 + Ar;
Thallium iodide (TlI) + $AlCl_3$ + Ar;
$SnCl_2$ + $AlBr_3$ + Ar;
Iron (II) iodide (FeI_2) + $AlBr_3$ + Ar;
TlI + NaI + FeI_2 + $AlCl_3$ + Ar;
NaI + $AlBr_3$ + Ar;
TlI + NaI + FeI_2 + $AlBr_3$ + Ar
InI + $AlBr_3$

The argon is used to increase overall vapour pressure and may be replaced by other noble gases, such as neon, helium or krypton.

It is further envisaged that the oxy-halides (i.e. oxychlorides, oxybromides or oxyiodides - X is Cl, Br or I) of certain metals, such as chromium (CrO_2X_2) and vanadium (VOX_2 and VOX_3), molybdenum (MoO_2X_2 and $MoOX_4$), and tungsten (WO_2X_2 and WOX_4) can be used in fills to produce visible light on excitation. Such oxy-halides are volatile liquids at room temperature.

Claims

1. A method of generating visible light from a discharge tube having walls made of a light-transmissive dielectric material, the discharge tube containing a fill comprising at least one compound selected from the group consisting of metal halides and metal oxyhalides, the method comprising the step of applying a radio frequency (r.f.) electric field over a part of a wall of the discharge tube at a power sufficient to excite a surface wave in the fill, whereby the fill is excited to generate visible light.

2. A discharge tube arrangement for generating visible light, the arrangement comprising a discharge tube having walls made of a light-transmissive dielectric material, the discharge tube containing a fill comprising at least one compound selected from the group consisting of metal halides and metal oxyhalides; the arrangement further comprising means for applying a radio frequency (r.f.) electric field over a part of a wall of the discharge tube at a power sufficient to excite a surface wave in the fill, whereby, in use, the fill is excited to generate visible light.

3. An arrangement according to Claim 2 wherein said means for applying an r.f. electric field comprises an r.f. power generator and a launcher.

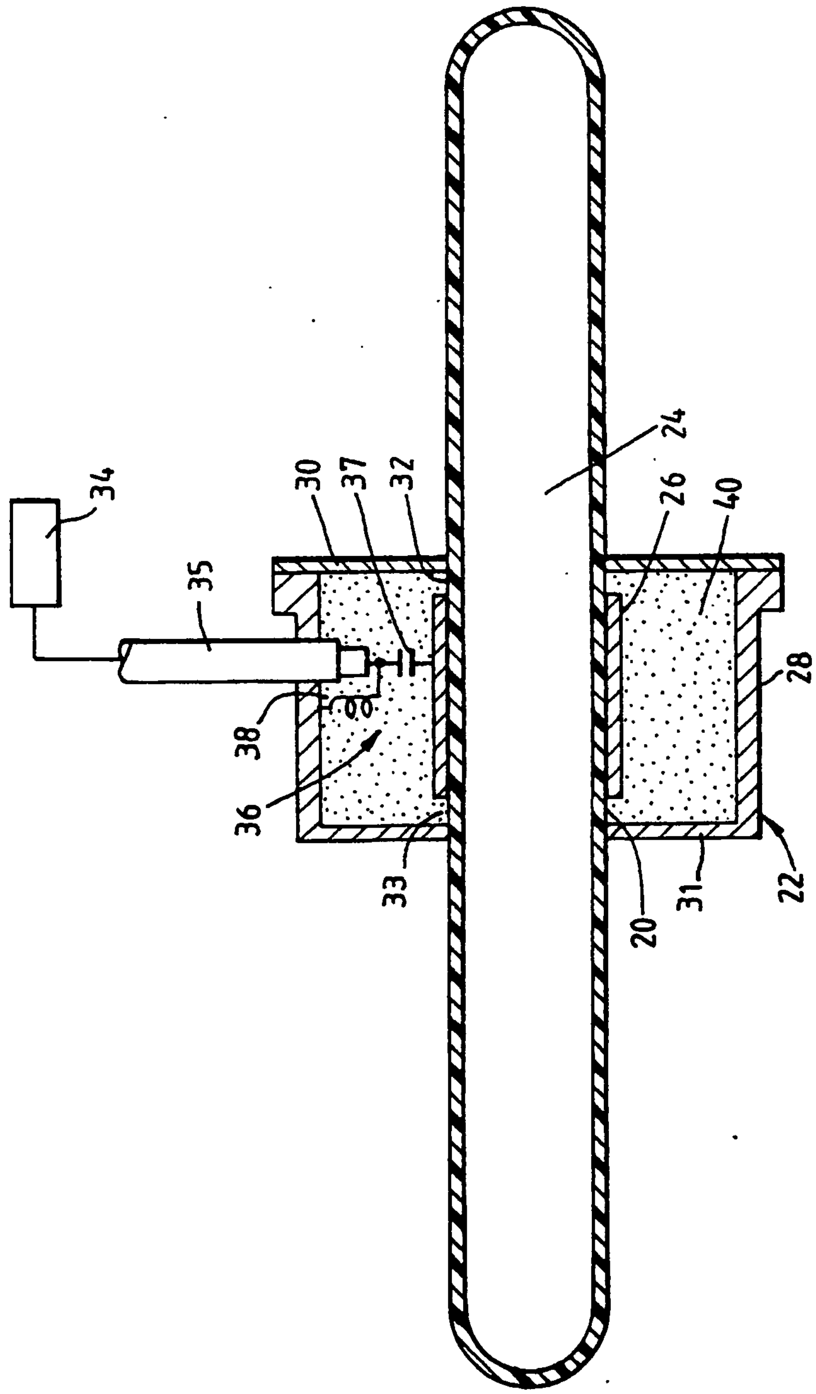
4. An arrangement according to Claims 2 or 3 wherein the fill comprises a halide of aluminium.

5. An arrangement according to Claim 4 wherein the fill comprises aluminium chloride.

6. An arrangement according to any one of Claims 2 to 5 wherein the fill comprises a halide of a transition metal.

7. An arrangement according to any one of Claims 2 to 6 wherein the fill comprises a complex of a metal halide.

8. An arrangement according to Claims 2 or 3 wherein the fill comprises a metal oxyhalide.



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